

Environmental management and sustainable development in forested mountain areas of northeast China

Cui Guofa (崔国发) Li Junqing (李俊清) Liu Jiagang (刘家冈)

College of Forest Resources and Environment, Beijing Forestry University, Beijing 100083, P. R. China

Wang Bennan (王本楠)

Eco-environmental Center, Chinese Academy of Science, Beijing 100083

Abstract This paper studied the sustainable development through a reasonable management of the social, economic and natural environment in a forested mountain area of northeast China. In order to show the local people how to manage their most important forest resource, we analyzed the life-history process of the key species and the influencing factors that were associated with the forest regeneration and sustainability. Pollination and fertilization were mainly affected by weather conditions. Light intensity under the forest canopy was the key factor that controlled seedlings growth and saplings survival. Periodic seeds setting caused the fluctuations of rodents and other related animals in the food chain. Squirrels played a very important role in the forest regeneration, these animals were the absolutely indispensable components of the forest ecosystem. How to understand the co-evolutionary relationships among species in the forest ecosystems was very important for the conservation of biodiversity and maintenance of ecosystem integrity. In conservation of the natural resources, we studied the social and economic environment of the forested mountain area. It is very hard to effectively protect the forest resources and maintain the normal life of the local people under the regime of the "unified administration and enterprise system". Reforms are needed both in administrative institutions and in enterprise management. In the end, this paper proposed that we should not only protect the trees, the related animals, the ecological habitats, and the whole forest ecosystems, but also consider the human activities and their basic requirements so as to realize a sustainable development in the forested mountain areas.

Key words: Sustainable development, Life-history, Environment, Resources, Administration

Introduction

It is well known that China has a long history and civilization, a large population and less cultivated land. This kind of situation is relevant to the resources depletion and recurrent natural disasters. Forests are very important both for the economical construction and for the environmental protection. The grave inundation that occurred at south and northeast rivers in the summer of 1998 gives us a bitter lesson; many scientists and masses believe that the long and over forest cutting should be responsible for the catastrophe. The forests on the middle and upper reaches of the Yangtze River and on the northeast mountain areas play an important role in reducing silt content and regulating volume of river flow for the two regions. Forests must be protected both in their biodiversity and in the total areas; particular attention should be paid to the northeast and the southwest parts that account for 71.7% of the total natural forests in China.

In fact, China has few forests, despite its relatively high absolute figures, the forest areas come out to only 0.115 hm² and 9.1 m³ per capita, as compared with the world average of 0.65 hm² and 75 m³ stock (Editorial Board of "China Conservation Strategy" 1990). China's forests cover only 13.2% of the national land, less than that of most other countries. Worse still, the forests are still being disrupted as the local people depend on, to a certain extent, the forests to live. What we can do is to encourage the local people to reasonably use the forest resources and to sustainably manage them without compromising the ability of future generation and only into meet their own needs (World Commission on Environment and Development 1987; Goodland 1995).

This paper takes the Korean pine forest as an example to analyze the natural forest ecosystem, life-history processes of trees, plant and animal interactions, and interrelationship between human activities, forest sustainability, as well as social and economic environment in China's northeast mountain areas. Korean pine forest is the climax and zonal vegetation type dominated by Korean pine (*Pinus koraiensis*), an evergreen and long life span species. Although the

forest is also distributed in Russia, Korea and Japan, northeast China is the center of its distribution. This type of vegetation has the most complicated structures and the highest diversities in the region. Unfortunately, it has been decreased rapidly since 1950s; for example, its area and its stocks have reduced to 56.0% and 70.4%, respectively, from 1949 to 1986 (Ma *et al.* 1992). Over-harvesting causes the forest degradation. Although tree cutting has been limited in the reserves, other perturbations such as seed collecting, hunting, and touring, etc., are not restricted or managed effectively.

For the sake of sustainable development we should consider the forest and human being as one system because the forest can never be avoided from the human influences. The object of our study is not the pure natural forest, but a man and forest integrated system. A sustainable ecosystem is one that, over normal cycle of disturbance events, maintains its characteristic diversity of major functional groups, productivity, and rates of bio-geochemical cycling (Holling 1986; Chapin & Tatenos 1996). Sustainable development requires maintaining the forest sustainable even when it is subjected to continuous human disturbances. Man and forests are closely interrelated, sustainable development has a working rationale only when the four dimensions of economic, the environmental, the social and the cultural development are discussed all together and in their interactions (Di Castri 1995).

Plant life history and forest sustainability under natural environment conditions

There are 4 main stages in Korean pine life-history process: Seed, Seedling, Sapling, and Mother tree. Accompanying with the different development stages, animals and some ecological factors play very important role in the sustainability of the Korean pine forest (Fig.1).

Fecundity and periodical seed production

Korean pine is a monoecism species. Pollination begins in June, cone matures in October of the next year. Seventeen months are needed for the pine seed production. Therefore, the ovules and seeds must avoid the following 4 killing factors before they could be developed to seed or be dispersed to a site for the germination and establishment: a) pollination failure; b) nutrient deficiency; c) perdition; and d) genetic abortion. Seed setting is greatly determined by microclimate and weather conditions. Rainy weather could decrease fertilization, late frost or cold spring affects trees to absorb water and nutrients, frequent occurrence of pest and disease damages the reproductive organs and juvenile seeds. Our

long-term observation and statistics show that seed production of Korean pine is not evenly every year and that is characterized by periodic good crop patterns. In about every 3a, there has a full seeding year. Periodic seed production is a genetic controlled phenomenon; one possible mechanism for the physiological rhythm is the large amount of nutrients depletion during the years of seed production, which limits not only the growth and development of the female flower, but also retards the primordial formation of the terminal buds in the following years.

Seed dispersal

Compared with other conifers, Korean pinecones are bigger and heavier. It is almost impossible for the fallen cones to be dispersed far away from the mother trees for the natural regeneration without animals that disperse or crack them, and release the seeds from them. Among these herbivores, squirrel (*Sciurus vulgaris*) is the most important agent for the seed bank dynamics and Korean pine regeneration. Our investigation shows that a squirrel cracks cones with its teeth, carries the seeds away in the mouth, and buries about 2~10 seeds, sometimes 20 seeds in the soil or under the forest litters randomly in the harvesting season of October and November. Some birds, such as Nutcracker (*Nucifraga caryocatactes macrorhynchus*) and Nuthatch (*Sitta europaea asiatica*) could also crack the cones and bury seeds in the forest floor. And it is just that these animals and useful birds disperse the cones and safely preserve the seeds that, then, germinate and recruit into seedlings. Korean pine seeds are transported to a suitable micro-site by animals during their predating process. In their searching and predating process the squirrels and other animals don't bury the seeds for the forest regeneration, but for their own consuming needs. The relationship between animals and Korean pine is perdition and regeneration; the mechanism is adaptation and co-evolution between prey and predators. These animals are used to burying seeds as the winter food, however, they cannot consume all the stored seeds. So that there always has some seeds left or even some sites forgotten by animals, therefore, natural regeneration is completed after the seed germination in seed storing sites. The fluctuation in Korean pine seed fruiting influence population size of squirrels or other animals, therefore, influences the carnivores that predate these herbivores as the preys. Increase in food (seed) supply stimulates the reproductive of rodents and other animals.

Germination and establishment

Seedling emergence in the forest is the results of the germination of seeds that have avoided perdition and happened to be transported in the safe sites. But,

during the first several days of emergence, rodents and birds could also damage the new recruited seedlings. Young seedlings are also selected by shade conditions under the forest canopy and the nutritional space competition with other plants. Our study shows that seedling density is $2340 \text{ individuals} \cdot \text{hm}^{-2}$, while the mother tree density is only $473 \text{ individuals} \cdot \text{hm}^{-2}$. The reason for this high mortality is environmental stress, mainly due to low light condition under forest canopy. Seedling height growth in Korean pine forest and Spruce-fir-Korean pine forest is $(1.333 \pm 0.25) \text{ cm} \cdot \text{hm}^{-2}$ and $(1.205 \pm 0.119) \text{ cm} \cdot \text{hm}^{-2}$, respectively, they are significantly lower than that under the deciduous forest canopy for $(1.882 \pm 0.332) \text{ cm} \cdot \text{hm}^{-2}$. Light intensity in the Korean pine forest composing mainly by the evergreen trees decreased to 1/3 of the secondary deciduous forests. When the seedlings in the deciduous forest are shaded, their height growth is also significantly decreased in comparison with the nearby control seedlings. The mean height growth of the shaded seedlings is only 73% that of the control. Shading has a great influence on the seedling growth. Further shading experiment in nursery shows that both height and root growths of the seedlings are significantly inhibited by the shading conditions. Both growing season (the deciduous tree possesses leaves) and non-growing season light condition influence seedling growth and development. The survived seedlings have succeeded in avoiding animal predation and tolerated the shaded conditions under canopy. Once they established, these seedlings could exist under the closed forest canopies for many years waiting for the formation of new gaps, which improved the forest light condition and release the seedlings and saplings from the impacts of the over-story trees. The patches under the new canopy trees will go through the next forest growth cycle by an alloiobiogenesis succession among the different aged trees. In natural conditions, Korean pine matures at about 120a, and good crops occur at about 140a. The pines could produce seed till 260 years old.

Pollination and seed development

Korean pine is a monoecy species. With the flourish of dormant buds and shoot extensions, female and male strobiles expand gradually. When the male strobile increases to 0.5 cm in length, the pollination begins in early June. The female strobiles open 7d earlier than pollen dispersal; they enlarge markedly and become dark purple and green after pollination. Meanwhile, the cones begin to develop, but they grow no more than 3 cm in the current year. The new cones continue growing and developing the next year. When the air temperature reaches to about 18.4°C , relative humidity reaches to 81%, and sunshine time reaches 8.3 h per day, the fertilization takes place

within the cones and the zygotes begin to develop. At this time, the cones have grown to the normal size. The seed scales dry up and split in 50-60 d after fertilization. However, a genetic disadvantage is that male strobiles locate at the middle and lower parts of the crown, while the female strobiles at the shoots and the crown tops. Pollens in the male strobiles can't be transported by gravitation. Wind is the most important agent for the pollination. If the pollen ripening and dispersal period happens to meet a long period of wet weather or lower air temperature, pollination would be seriously inhibited. Our investigation shows that about 50% flower buds of Korean pine wither, even for those flourish buds, 10% of them could not develop to the ripen cone stage. In addition, about 4.5% young cone withered up. The mature cones are only small parts of the potential cones. In short, the natural process of Korean pine development will pass through 4 main stages from seed to mature tree (Fig. 1). Environmental conditions, especially the rodent predating, are indispensable for the pine life cycle although some of them have positive function to the ecosystem sustainability; some of them have negative or impact to the forest development processes. The natural forest ecosystem will keep stable development without the human influences. That means the ecosystem's inertia in the face of change, and its ability to return to a former succession status after being degraded or deflected by outside disturbance.

Human influences to the forest ecosystem and environment sustainability

It is almost impossible to keep the forest ecosystem from human impacts, especially in the over populated China. Human activities influence every aspects of forest ecosystem, even in some natural reserves. Man and natural forest form an integrated system (Fig.1). Forest management has to consider not only to the forest itself, but also the human life and human activities in the forested area. Man has become a central object in the ecosystem management, so our management is no longer an ordinary forest management, but an environmental management in which man is the central object of our management.

Forest cutting

Forest cutting can not only remove the woods but also decrease the biodiversity. Some rare and endangered species are disappearing with the frequent forest cutting, which causes rapid decrease of forest resources and environmental degradation: desertification, soil erosion, river sedimentation and blocked channel. All of these disasters were observed and noticed by government officers and local people.

There are also some profound influences: large amount of forest cutting and human colonization changes the vast continued forest area into patches, forests were separated by the new human constructions and agricultural lands. That is one of the most important impacts for the species distinction, especially for the large mammals. Siberian Tiger (*Panthera tigris altaica*) is an endemic and precious animal in the Korean pine forest of northeast China, but it is extinguishing from the Earth owing to the less and

less suitable habitat. Although three Natural Reserves have been established in Changbai Mountain, Liangshui and Fenglin of northeast-forested areas, they are not connected in space; the nearest distance between them is several hundred kilometers. We doubt that if the protected area in the natural reserve can meet the minimum area need of an effective population size for Siberian Tiger to predate, to reproduce, and to hide in the natural environment.

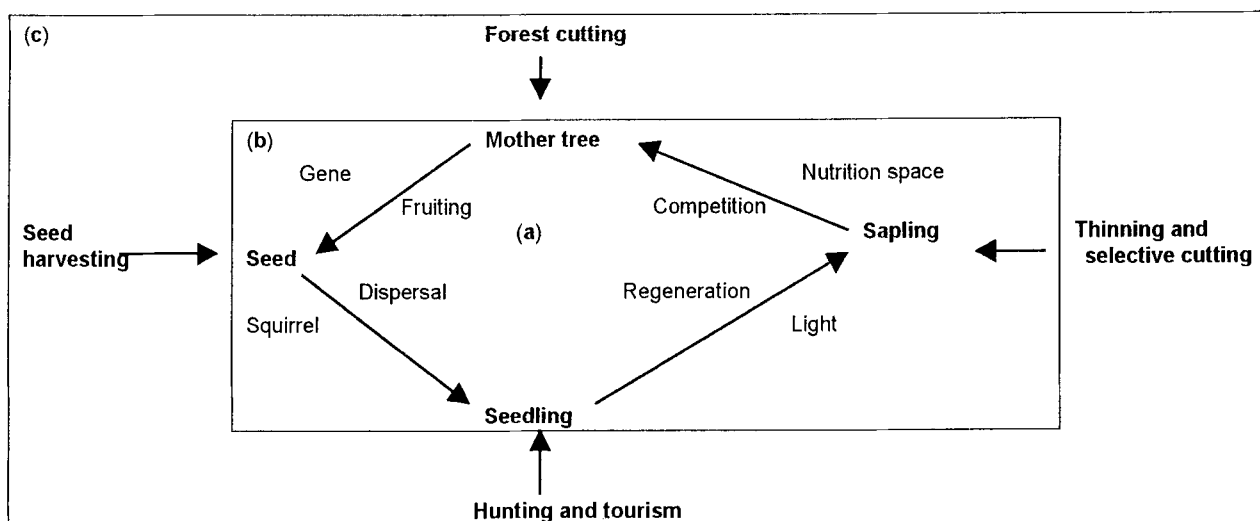


Fig. 1. Man and forest integrated system

- (a) Korean pine life-history process: The mother trees produce seeds through fruiting by genetic control. The seeds germinate and transform to seedlings through dispersal by animal control (squirrels and useful birds, etc.), the seedlings survive and grow into saplings through regeneration by light control (environmental factors), and the saplings develop to the mother trees through competition by nutrient space control.
- (b) The natural forest ecosystem without human activities is stable.
- (c) The whole components constitute a man-forest-integrated system in which man is the central object. Sustainable development should rationally manage the forests to meet the needs of human activities, and to solve social and environmental problems of the local people.

Seed harvesting

Great quantity of seeds harvested by man has seriously damaged the nature Korean pine trees and the forest regeneration. Human harvesting seed is not by means of collecting the fallen cones on the forest ground, but by climbing on the crown to harvest the cones because the local people would not like waiting for the seeds to be "consumed" by animals or collected by "other people" when seed matures. Sometimes, seed harvesters have to cut or break branches in order to get the cones in the top trees. Seed harvesting damages pine crown, decreases mature branches and finally influences fruiting of the next year. In addition, immaturity seeds are difficult to germinate and sometimes decomposed in the forest floor or soil before the germination, so that the local people use large amount of the seeds for food. With the rapid development of tourism in the forest areas, pine nut has become a very famous dish in the north-

east China. Pine nut food was limited only in the forest farm 10~20 years ago, and now it has been developed in quality and diversified in quantity. In many restaurants pine nut foods are perhaps the first choice for many tourists both in forest region and in some big cities.

Intensive pine seed harvesting has badly affected seed dispersal, especially seed buried by animals, such as squirrels and birds. The decrease of these herbivores limited, in turn, their predator's natality, reproductively and survival rate, such as Golden eagle (*Aquila chrysaetos*) and Brown hawk owl (*Ninox scutulata*) in the forest. Squirrels and other pine nut predating birds are the tree-nested species, which is easy for the bird of prey to hunt them. However, most of the harmful rodents are the cave-nested species and it is difficulties for the birds of prey to kill them in the forest caves. These harmful rodents eat not only the left cones and seeds but also the young seedlings if there has no enough seed food in the

forest. In short, human harvesting interrupted Korean pine regeneration, which was the basis to maintain sustainability of the forest ecosystem. Over harvesting of pine seeds causes the Korean pine forest decline immediately or in 10, 50 to 100a.

Hunting and tourism

Hunters always kill the animals that have important economic values and just these animals play a very important role in the forest regeneration and food chain stability. Stimulated by period good crops carnivores such as Siberia weasel (*Mustela sibirica*), Red fox (*Vulpes vulpes*) and other birds of prey increase their population size to a relatively high amount about every 3a, too, but 1 and 2 years later following the good crop of Korean pine. The carnivores could play the function of controlling the herbivore amount because they predate a lot of rodent and other harmful animals. But hunting disturbs the equilibrium relation between pine and herbivore and between herbivore and carnivore. So the harmful animal amount increases in the Korean pine forest rapidly after the good hunting years. Sometimes, these herbivores have to browse pine seedlings if they are over populated, if men harvest over the pine seeds, and if the carnivores are hunted quantitatively in the Korean pine forest. Many tourists are interest very much in the special forest food that is, perhaps, one of the most important intention for the tourists to visit in the forest areas. The hunters are encouraged by the good market value of the animals that could serve a delicious dish for the tourists.

Thinning and selective cutting

Thinning is a necessary silvicultural practice of forest management for the young seedlings growth or saplings. It regulates inter-specific relations and light competitions among different species, and, therefore, benefits the desirable trees to grow in a suitable habitat. However, thinning is very expensive if the intermediate felling trees could not be sold in the market, whereas the local people has to select the saplings or young trees that have reached to the size and quality of economic value even at the first time of forest tending and sell the cut wood for the cost recovery. Selective cutting causes the same problem as thinning in the silvicultural practices. It has been known that the valuable saplings or young trees are always the co-dominant ones. Cutting of them might leave the cull or minus trees in the forest as the standers. So the forest quality decreases after thinning and selective cutting. Particularly the genetic superior trees are cut before they ripen enough to be fruit setting. The long-term impacts thinning and selective cutting will be the grave and unpredictable to the sustainable development of the Korean pine forest.

Social and economic environment of the forested mountain areas

The most important reason for the inevitability of the human intervention in the natural forest ecosystem is the social and economical environment in the forested mountain areas. In China, there exists a social and economical system of "Unified Administration and Enterprise (UAE)" in some industries of rich in natural resources, such as coal, petroleum, gas, mineral, forestry, etc. (Fig. 2).

The government bodies and the producing enterprises are the same unit. It plays important roles in both a government and an enterprise so that it is in charge of both political power and economical development. This kind of unit must seek effective administration and maximum economic results. In some forested mountain areas, forest bureau is the basic administrative unit and the UAE system is the main social and economical administrative agent. It has played a very important role in the forestry industry and contributed a great deal to the national development. Although it has been much improved with the recent years' reforms, the relative industrial structure, the main administrative system and the social and economical environment can not be changed at one night. In most of the forested mountain areas the main commodities of merchants are wood and wood products, the most important products of factories are woody furniture or forestry machines.

Initially, there were no other industry branches except for the vast forests, forestry workers and their families in the forest bureau. With the economic development, population increase, massive migration, and forest decrease other industry organizations appear progressively. Now, a full society and administrative system has been established. A forest bureau is, based on its dimension and population, a county or a town (district). It serves both as a power organization to administer all aspect of the social and politic affairs in the region and as an enterprise to run the forest management and wood production. For the forestry workers, forest bureau is responsible both for their work and for their social activities. Facing to the rapid decrease of forest resources, the Chinese government has launched a "Natural Forest Protective Program". The aim of the program is to stop cutting and protect the forests from human disturbances. Most of the forestry workers will lose their ordinary forestry work of wood logging, tree cutting, and their main income resource, etc. Forestry bureau must take care of their jobs and their daily lives for the local people. How can the forests be protected without considering the human activities, social and economic environment in the forested mountain ar-

eas?

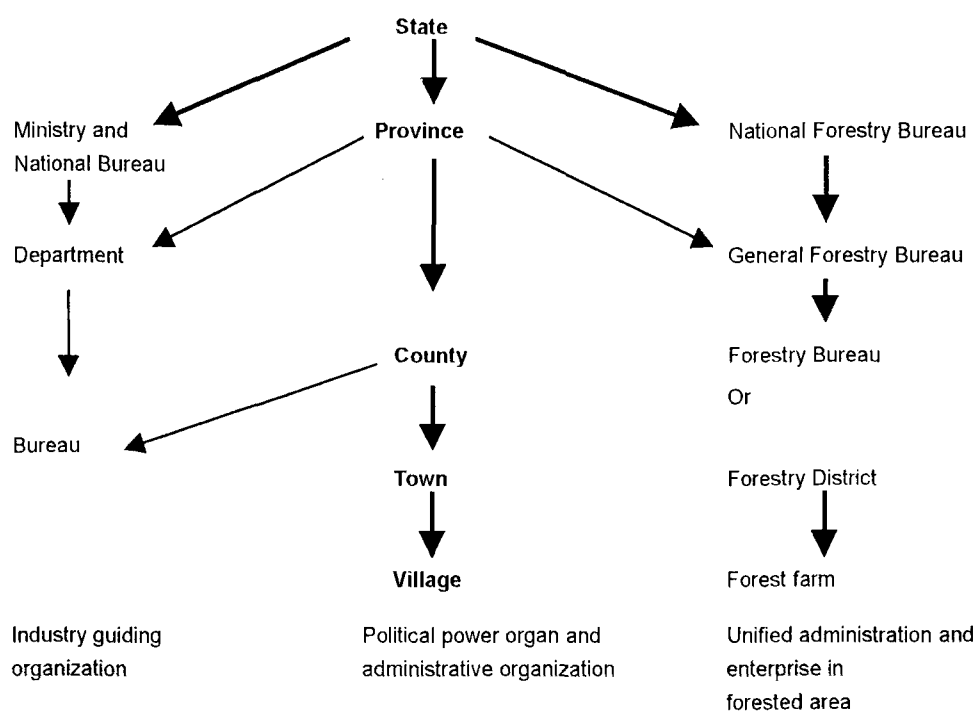


Fig. 2. The "Unified Administration and Enterprise (UAE)" system

Government bodies and the producing enterprises are the same unit in the forested mountain areas. Forest bureau is the basic administrative unit that is correspondent a county or a district in a general administrative system. It serves both as a power organization to administer all aspects of the social and politic affairs in the region and as an enterprise to run the forest management and wood production. For the forestry workers, forest bureau is responsible both for their work and for their social activities.

The thick arrow line represents the relations of government administration; the thin arrow line represents the relations of industrial guiding organization.

Discussion on environmental management and sustainable development

Sustainability means a number of things; this is an idea that is both simple and complex. On the one hand, it is hard to argue with the goal of preserving the earth and leaving communities undisturbed. On the other hand, it sounds unrealistic. How can bridges and roads be built? Enough food is brown, enough trees are harvested, and enough dams are constructed without doing some damage. And how can investors be induced to support development activities in which they are constrained from doing a reasonable profit (Johnson 1998)?

World Commission on Environment and Development (1987) pointed that economic growth and development must involve the changes of the physical ecosystems. Ecosystem everywhere cannot be preserved intact. A forest may be damaged in one area and established elsewhere, but exploitation should be planned and effects on soil erosion rate, water regimes, and genetic losses should be taken into account before and during the exploitation. In general,

renewable resources like forests will not be depleted provided that the rate of use is within the limits of environmental capacity.

In order to protect natural forests, we could strictly prohibit the seed harvesting, the hunting, and the cutting. But it neglects the local people who depend on the forests and the forest bureau to live. We cannot develop sustainable without fully considering the human needs and the human activities. UNCED (1992) Agreement on forest proposed that forest resources and forestlands should be suitably managed to meet the social, economical, cultural and spiritual human needs of present and future generations. Preliminary study (Li & Gu 1988) shows that we can collect a certain amount of pine nuts and hunt a certain number of animals during and after the fruiting years. The controlled harvesting provide necessary sources for the local peoples who will be encouraged to protect the forest actively for their further exploitations, and that will not damage the forest sustainability.

Modern conservation theory has broadened from the past emphasis on strict protection area, primarily for large mammals, to an emphasis on sustainable

resource use, maintenance of ecological processes, and genetic diversity (IUCN 1980). It is also widely acknowledged that the conservation of forest resources can not be sustained in the long term without the acceptance and support of the surrounding human population. Cunning (1989) pointed that the use of plant resource to meet human needs is an important aspect of the multiple-use of land in many parts of Southern Africa. Indigenous plants, for example, are source of fuel, medicine, building material, craft-work material, dye, income and food supplements. The rural sector of this population is particularly dependent on indigenous plant resources, although urbanization does not preclude the use of wild plant resources. Herbal medicines, fuel wood, wild spinaches and mat-rush (*Jun*) sleeping mats are all items of trade from rural source area supporting an urban demand.

Morowitz (1991) pointed that the continuing growth of human population requires ever more land for housing and agriculture to increase habitat destruction. The over populations in China are both an economic and a social problem for the future development. Facing the ever-growing population pressure and the basic life requirements, such as foods, houses, and clothes we must chose a better way to develop sustainable. Di Castri (1995) pointed that sustainable development can then be figuratively represented as a robust chair with four legs of equivalent length and strength, each one of the legs being- alone and with its interactions- a main component of development. If one leg of the chair is shorter or weaker than the others, there is no comfortable 'sitting-down' state, nor sustainability.

We have found that the most severe threat to the forest sustainability comes from population pressure. Conservation is relatively easy to be put in practice if we don't consider the local people; in fact we cannot forget that all the forest area even the protected area support to local populations. Removal of resources from local control has never a positive effect on biodiversity conservation (Halffter 1996). McNeely (1996) pointed that biological resources are often under threat because the responsibility for their management has been removed from the people who live close to them. Perhaps the biggest failure in resource management has been the widespread neglect of the dynamics of the exploiters. Hilborn, *et al.* (1995) remarked that it has proven almost impossible to prevent fish-men from increasing their harvesting power. The only effective management is the property rights that change the economic incentives for individuals. We think the same is true in the forestry that the most successful institution for promoting sustainable exploitation of forest has been the private ownership. The private ownership may encourage to convert as

many of the local people as possible from the "eco-system people" into "biosphere people", making them part of global consumer culture (McNeely, 1996). We must consider the forest's ability to fulfil economic, social and ecological functions.

Sustainable development is the new paradigm, the new way to consider the whole of human society and its relationship with natural environment. Progress toward sustainable development requires a profound understanding of the earth's ecosystem (Bourdeau 1996). The complex life history processes of Korean pine populations, the inevitable human activities, and unified administration and enterprise raise great challenges to ecologists and environmental protectors. Although rodents consumed vast amount of seeds, forest regeneration and establishments are quietly dependent on these animals to disperse and bury the heavy seeds (Li & Gu 1988; Li & Zhu 1991). The life-history pattern studies for the Korean pine populations are one of the central issues to understanding evolution and conservation of this species and the related forests. More human activities have made the ecosystem complicated because this ecosystem is no longer an absolute natural one, but a social, economical, cultural and ecological integrated system. Forest resources have an instrumental value that can contribute directly or indirectly to human needs. Future generations are implicitly taken into consideration by managing the resources without hampering their needs (Linddal 1994), sustainability of forest ecosystems is necessary and the development of human society is more important.

References

- Bourdeau, Ph. 1996. Environmental ethics and biodiversity. In Biodiversity, Science and Development (F. Di Castri, T. Younès, eds.). Paris: CAB INTERNATIONAL, pp.617-621
- Chapin, F.S., Torn, M.S. and Tatenos, M. 1996. Principles of ecosystem sustainability. *The American Naturalist*, **148**(6): 1016-1037
- Cunningham, A.B. 1989. Indigenous plant use: balancing human needs and resources. In: Biotic diversity in Southern Africa (B. J. Huntley, ed.), Cape Town: Oxford University Press, pp.93-106
- Di Castri, F. 1995. The chair of sustainable development. *Nature and Resources*, **31**(3): 2-7
- Editorial Board of China Conservation Strategy. 1990. China Conservation Strategy. Beijing: China Environmental Press
- Goodland, R. 1995. The concept of environmental sustainability. *Ann. Rev. Ecol. Syst.*, **26**: 1-24
- Halffter, G. 1996. Biodiversity conservation and protected area in tropical countries. In: Biodiversity, Science and Development (F. di Castri, T. Younès, eds.). Paris: CAB

- INTERNATIONAL, pp.212-223
- Hilborn, R. Walter, C. J. and Ludwig, D. 1995. Sustainable exploitation of renewable resources. *Ann. Rev. Ecol. Syst.*, **26**: 45-67
- Holling, C.S. 1996. Resilience of ecosystem: local surprise and global change. Page 292-317 In: *Sustainable development and biosphere* (W. C. Clark and R. E. Munn, eds.). Cambridge: Cambridge University Press, Cambridge
- IUCN. 1980. *World conservation strategy: Living resource conservation for sustainable development*. IUCN/WWF, Gland, Switzerland.
- Johnson, I. 1998. Letter from the new vice president environmentally and socially sustainable development. *Environment*
- Li Junqing. 1988. Mathematical model for dynamics of seeds, squirrels and seedlings in the Korean pine forest. *J. Northeast Forestry University*, **16**(4): 44-51
- Li Junqing and Zhu Ning. 1991. Structure and process of Korean pine population in the natural forest. *Forest Ecology and Management*, **43**(1): 125-135
- Linddal, M. 1994. Sustainable development of temperate forests- from sustained yield to sustainability. In *Models of sustainable development. Exclusive or complementary approaches of sustainability?* (International symposium). Paris: Université Panthéon-Sorbonne, pp. 359-374
- Ma Jianlu and Zhuang Liwen. 1992. The geographical distribution of Korean pine (*Pinus koraiensis*). *J. Northeast Forestry University*, **20**(5): 40-48
- MecNeely, J.A. 1996. Conservation biodiversity: the key political, economic and social measures. In: *Biodiversity, Science and Development* (F. Di Castri, T. Younès, eds.). Paris: CAB INTERNATIONAL, pp.264-281
- Morowitz, H.J. 1991. Balancing species preservation and economic considerations. *Science*, **253**: 752-754
- UNESCO. 1992. Non-legally binding authoritative statement of principles for global conservation on the management, conservation and sustainable development of all types of forests. United Nations Conference on Environment and Development (UNESCO). Rio de Janeiro, 3-14 June
- World Commission on Environment and Development. 1987. *Our common future*. Oxford, New York: Oxford University Press